(54) Title: ENTERTAINMENT AND CREATIVE EXPRESSION DEVICE FOR EASILY PLAYING ALONG TO BACKGROUND MUSIC

(57) Abstract

An electronic entertainment device allows an untrained vocalist or instrumentalist to easily synthesize an instrumental lead with one or more harmonies playing along with predefined background musical sequences. While background parts are being played by the device or any musician, the user plays the melody or lead by humming, singing, whistling or operating any tone-producing device such as a musical instrument into the device. A pitch extractor (102) identifies the pitch. A tone filter (107) compares the pitch with a table (105) of allowable pitches as dictated by predefined data associated with the background music and chooses an appropriate output tone to drive a music synthesizer (110). The note which is produced by the device is one which sounds pleasing in the context of the musical background. The device facilitates an active involvement in music expression without a need for well developed skills as a vocalist or instrumentalist.
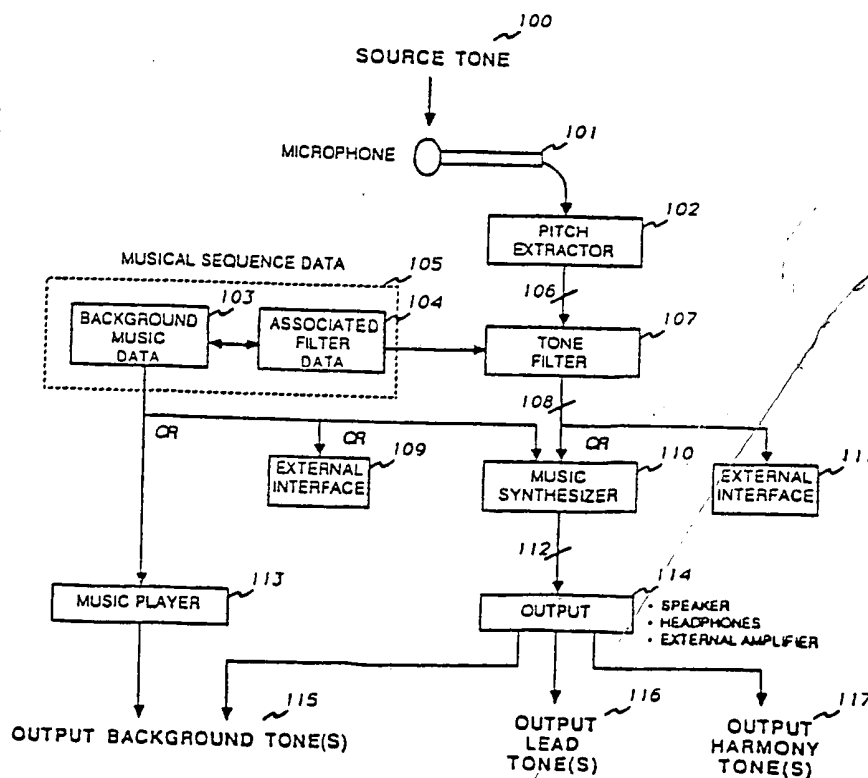
WO 88/05200

ENTERTAINMENT AND CREATIVE EXPRESSION DEVICE
FOR EASILY PLAYING ALONG TO BACKGROUND MUSIC

BACKGROUND

Field of the Invention

This invention relates to electronic musical
instruments which are simple and fun to use and more
particularly to a voice controlled musical instrument.

Description of the Prior Art

Musical instruments have traditionally been
difficult to play, thus requiring a significant
investment of time and, in some cases money, to learn
the basic operating skills of that instrument. In
addition to frequent and often arduous practice
sessions, music lessons would typically be required,
teaching the mechanical skills to achieve the proper
musical expression associated with that instrument,
such as pitch, loudness, and timbre. In addition, a
musical language would be taught so that the user would
be able to operate the instrument to play previously
written songs.

The evolution of musical instruments has been
relatively slow, with few new musical instrument
products taking hold over the past several hundred
years. The introduction of electronics-related
technology, however, has had a significant impact on
musical instrument product development. The music
synthesizer, for example, together with the piano
keyboard interface/controller, has vastly expanded the
number and variety of instrument sounds which can be
produced by a person who has learned to play a single

-2-

instrument -- that of piano or keyboards. The
requirement remained, however, that for someone to
operate a synthesizer, that person would have to learn
at least some of the fundamentals of music expression
associated with playing a piano.

Therefore, for those people who wanted to be able
to express themselves musically, but had not learned to
play an instrument, or wanted to be able to make many
instrument sounds without learning how to play each
instrument, there was still a significant time
investment required to lea n the skill, with no
assurance that they could ever reach a level of
proficiency acceptable to them.

A variety. of methods have been proposed to use the
human voice to control a synthesizer, thus taking
advantage of the singular musical expression mechanism
which most people have virtually anyone who can speak
has the ability to change musically expressive
parameters such as pitch and loudness. One such method
is described in U.S. Patent No. 4,463,650, by Robert
Rupert, issued August 7, 1984 incorporated herein by
reference. In the Rupert device, real instrumental
notes are contained in a memory with the system
responsive to the stimuli of, what he refers to as,
"mouth music" to create playable musical instruments
that will respond to the mouth music stimuli in real
time.

The difficulty in practice with using the voice as
a controller of a musical synthesizer is that some
people have little real or perceived ability to reach
pitches in a manner accurate enough to believe they
sound good. Even trained vocalists have vocal
characteristics such as frequency and interval which
are unstable and to some degree inaccurate. Such

-3-

frequency error or instability goes virtually unnoticed by any one who hears the vocal tone directly. However, the frequency error or instability of the output tone signal can be distinctly perceived by any one when he hears a vocal tone processed by a conventional voice-controlled music synthesizer, as that suggested by Rupert. As a result, there is some segment of the population which may not perceive the voice controlled music synthesizer, alone, as a viable route to personal musical expression and/or entertainment.

One such solution is described in European Patent Application No. 84307003.8, by Ishikawa, Sakata, and Obara, entitled "Voice Recognition Interval Scoring System", dated May 29, 1985. In this patent, Ishikawa et. al., recognize the inaccuracies of the singing voice and "contemplates providing correcting means for easily correcting interval data scored and to correct the interval in a correcting mode by shifting cursors at portions to be corrected". In a similar attempt to deal with the vocal inaccuracies, a device described in U.S. Patent No. 3,999,456 by Masahiko Tsunoo et al, issued December 28, 1976, utilizes a voice keying system for a voice-controlled musical instrument which limits the output tone to a musical scale. The difficulty in employing either the Ishikawa or the Tsunoo devices for useful purposes is that most untrained musicians will not know which scale The appropriate for different songs and appli ed device may even be a detractor from the ch certain voice-controlled music synthesizer, frustration of the user not being fined usually notes he desires to play.

In a related area, the "music-minus-one" is the

-4-

prerecorded musical background to supply contextual music around which a musician/user sings or plays an instrument, usually the lead part. This concept allows the user to make fuller sounding music, by playing a key part, but having the other parts played by other musicians. Benefits to such an experience include greater entertainment value, practice value and an outlet for creative expression.

SUMMARY DESCRIPTION OF THE INVENTION

The invention disclosed herein is an enhancement on the music minus-one concept, providing a degree of intelligence to the musical instrument playing the lead the voice-controlled music synthesizer, in this case so as not to produce a note which sounds dissonant or discordant relative to the background music. In addition, this invention is an improvement on the voice-controlled music synthesizer, by employing correction, but in such a way that the device can be used and enjoyed by all parties. Rather than correcting the interval in an arbitrary manner, as suggested in the Tsunoo and Ishikawa patents, this device adjusts the output of the music synthesizer to one which necessarily sounds good, to the average listener, relative to predefined background music. The key advantage of this invention is that it allows any person with speaking ability to be able to express himself/herself musically and sound good doing it, with virtually no training. Such a device can provide useful entertainment and/or creative expression value to a large number of people. In addition, it can help people learn to improvise and play music "by ear".

The entertainment and creative expression device disclosed in this application is comprised of pitch

−5−

extraction means for determining pitch from a sound
source, a means for storing and transmitting background
music information, such as note pitches and intervals
and background instruments selected, a means for
storing and transmitting relevant allowable, or
pleasant sounding, lead tone and harmony tone data
associated with the background music, a means for using
the associated filter data to translate the tone
determined from the pitch extraction means raw
frequency or pitch data extracted from the source tone
to a tone determined to be allowable as defined in the
associated filter data, music synthesizer means for
musically synthesizing the output tones from the output
tone data, and a means for synthesizing, transmitting,
or reproducing the background music from the background
music data.

Other objects, features and advantages will be
made clear from the following description of
embodiments thereof considered together with the
accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic block diagram of an
embodiment of the voice controlled entertainment device
for easily playing along to background music, made in
accordance with this invention;

FIG. 2 illustrates three examples of filter schema
"filter tables" of varying degrees of correction;

FIG. 3 illustrates some of the options regarding
changing of the filter schema or tables during or
between musical sequences songs;

FIG. 4 pictorially illustrates one of the
preferred embodiments of the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIG. 1, a Source Tone 100 is received by the entertainment and creative expression device disclosed herein. The sound source can be single or multiple tones produced by a human voice singing voicing or not voicing words, humming, whistling, talking, using any single syllable such as "doo, doo, doo" or "lah, lah, lah" at varied pitches, or multiple syllables at varied pitches, or any audio apparatus which can produce tones, such as acoustic or electric or electronic musical instruments, for example, recorders, whistles, trumpets, electric guitars and the like. Each "tone" contains a fundamental frequency identifying a pitch together with a start time and duration. A sequence of pitch, start time and duration data defines a "tone sequence", "tune", "musical sequence", or "song" these terms are used interchangeably.

The introduction of the tone into the device can be either through a built-in microphone 101, external microphone, or specialized audio sensing device, such as a guitar "pick-up". For purposes of this application, the term "microphone" represents all such devices. The source tones which are introduced into the device through the microphone 101 are the basis for controlling musical tones which emerge from the device which will sound pleasing relative to predefined background music.

The input signal which is detected by the microphone 101 is analyzed by the pitch extractor 102 to determine at least the fundamental frequency or pitch of the source tone. A variety of approaches exist to detect fundamental frequencies from analog signals. One such approach is described in U.S. Patent

-7-

No. 4,202,237, dated May 13, 1980, by Bjarne C.
Hakansson. Hakansson's invention extracts a
fundamental frequency from signals coming from played
musical instruments. Another such approach is
described in U.S. Patent No. 4,457,203, dated July 3,
1984, by Schoenberg et al. Schoenberg's patent
describes a device which can automatically detect and
display the fundamental frequency from sound sources
with continuous frequency ranges such as the human
voice.

The device's input or source tone 100, associated
output tone, and associated tone-in-process at any
stage within the device, are referred to herein as the
"lead". The lead can be any tone or sequence of tones
which the user desires, including the user's idea of a
melody associated with the respective background music,
the actual melody associated with the background music,
a harmony associated with the background music, or a
sequence totally unassociated with the intent of the
author of the musical piece comprising the background
music. The output tone associated with the lead is
referred to as the "output lead tone" 116.

In addition to being able to generate an output
lead tone 116 from the respective source tone 100, the
invention optionally generates another output tone
associated with the output lead tone 116 and the output
background tones 115 - analog tones of the background
music called, in this application, an output harmony
tone or tones 117. The output harmony tone is an
output tone which appears to "follow" or "harmonize"
with the lead tone, in such a way as to sound pleasant
relative to the output background tones 115.

The memory means 105 - "musical sequence data" or
"song data" for the background music, along with which

- 8) -

the user is playing the lead, contains the background
music data 103 and the associated filter data 104. The
musical sequence data is a necessary component of he
invention. The background music data 103 can be any
sequence of single or multiple notes which creates a
context of musical information along with which the
device's user can play a lead. The tone sequences can
form recognizable songs, or parts of songs, generic
patterns of tone sequences associated with certain
musical styles, such as rock, folk, blues, jazz,
reggae, country, and classical, or any other sequence
or sequences of tones. The sound types used to play
these note sequences can be pitched or nonpitched,
having timbres or sound personalities associated with
traditional musical instruments, electrical musical
instruments, electronic or synthesized musical
instruments, known or unknown sound effects, or any
other type or types of sounds. For purposes of this
specification, these tone sequences are referred to as
"background music" or "background music data".

The media which is used to store the musical
sequence data in 105 can be read-only-memory ROM
circuits, or related circuits, such as EPROMs, EEROMs,
and PROMs; optical storage media, such as videodiscs,
compact discs CD ROMs, CD-I discs, or other, and film;
bar-code on paper or other hard media; magnetic media
such as floppy disks of any size, hard disks, magnetic
tape; audio tape cassette or otherwise; phonograph
records; or any other media which can store digital or
analog song data or songs, or a hybrid of analog and
digital song data or songs; or any combination of media
above. The medium or media can be local, or resident
in the embodiment of the device, or remote, or
separately housed from the embodiment of the device.

The associated filter data 104 must necessarily be used by the device, either directly read from the storage media, or after any processing inside, or outside the device, to establish relevant allowable output tones from the source tones.

The musical sequence data storage means 105 communicates the associated filter data 104 to a tone filter 107 which accepts at least the raw frequency or pitch data 106 from the pitch extractor 102 and translates the raw frequency or pitch data 106 and any other relevant tone data to relevant allowable output tone data 108 in accordance with the associated filter data 104 predefined for the background musical sequence 103 being played. The allowable output tone data will include, at the minimum, data regarding the output lead tone 116, and may optionally include data regarding the output harmony tone or tones 117. The output harmony data can be data describing one, two, or more tones generated simultaneously. Both output lead data and output harmony data is determined by the tone filter 107 which utilizes the filter data 104 associated with the background musical data 103 to analyze and process the raw frequency or pitch data 108 from the pitch extractor 102. Examples of implementation means for translating the raw frequency or pitch information 106 into output tone data 108 are illustrated in FIG. 2 and FIG. 3, and described in detail later in this specification.

The output tone data 108, at least the output lead tone data, and optionally the output harmony tone data is then transmitted to a music synthesizer and converted to analog musical output tones 112 synthesizing musical instruments of known timbre, timbre which is similar to known timbres, or unknown

-10-

timbre, or sound effects, in accordance with the
defined output tone data. The user may either be
allowed to define which timbre to choose for the output
tone or tones, or the musical sequence data 105 will
specify the appropriate timbre or timbres, or the
device will be implemented so as not to offer a choice
to the user as to timbre for the output tone or tones.

One implementation of the invention has the output
tone data transmitted to an external interface 111
which allows the information to be used to drive an
external music synthesizer, and/or to be transmitted to
an external sequencer or recording device, computer,
printer, another voice-controlled entertainment and
creative expression device such as that disclosed
herein, or any other external device for accepting
and/or processing the output tone data. The interface
may be an accepted standard, such as RS-232 or MIDI
Musical Instrument Digital Interface, or any other
communicating or interface means.

Concurrent with the transmission of the output
tone data 108 to the music synthesizer 110, the
background musical data 103 is transmitted to a music
synthesizer (either the same 110 as that used to
generate the analog musical output tones 112 or a
different one) and converted to analog musical output
tones 112 synthesizing musical instruments of known
timbre, timbre which is similar to known timbres, or
unknown timbre, or sound effects, in accordance with
the defined background music data, or transmitted to an
external interface 109 similar to 111, or transmitted
to another musical player, such as a phonograph, radio,
stereo, tape player, compact disc player, videodisc
player, video tape player or any other sound generating
device. The user may either be allowed to define which

timbres to choose for the output tones or the musical
sequence data 105 will choose the appropriate timbres,
or, in some low cost embodiments the device can be
implemented so as not to have a choice as to timbre.

The analog musical output tones are transmitted to
the user through output means 105 such as speaker,
headphones, display, external amplifier and associated
speaker, or any other audio transmission means.

FIG. 2 illustrates three examples of filter schema
107 employed at any discrete point in time during the
operation of the entertainment and creative expression
device disclosed herein. For these examples, the
source tone introduced into the entertainment and
creative expression device is a whole note which has a
pitch 202 squarely on a D note of any octave, and
therefore, the tone's raw pitch 106 detected by the
pitch extractor 102 is that of a D. The examples show
the use of "the key of A" 200, as represented by three
sharps 201 as illustrated on the musical staffs in FIG.
2, as the filter's reference scale, and illustrates
three degrees of correction or conversely three degrees
of freedom which can be employed using the scale in the
key of A. These examples are the "diatonic scale
filter" 203, the "pentatonic scale filter" 206, and the
"melody filter" 208, in order of decreasing degrees of
freedom, or increasing degrees of correction,
respectively.

In the diatonic scale filter example 203, the
allowable tones are the seven notes 204 at any octave
of the A major scale, or the notes A, B, C#, D, E, F#,
and G# illustrated in FIG. 2 by showing the whole notes
in the scale as open or clear in the center 209. Not
allowed would be all tones with pitches between notes
in the A major scale. Since the pitch of the source

-12-

tone is D 202, the output lead tone data will include
the pitch designation of D 205, implementing no pitch
correction on the source tone.

In the pentatonic scale filter example 206, the
allowable tones are the five illustrated notes A, B,
C#, E, and F# open whole notes 209 on the staff in 206.
The tones in the scale which are not allowed are D and
G# closed whole notes 210 on the staff in 206. · Also
not allowed are all tones with pitches between notes in
the A major scale. Since the pitch of the source tone
in this example is D, the pitch will be corrected by
the tone filter to become the closest tone in the
allowable tone set, which in this case is C# 207.

In the melody filter 208 example, the allowable
tones are limited to the single note at all octaves
which is designated as the singular lead tone intended
for that point in the musical sequence, wherein named
the melody tone. In this example, the filter schema
and musical sequence data define A 211 to be the
allowable melody tone. Since the pitch of the source
tone in this example is D, that pitch will be corrected
by the tone filter, in this example to the nearest A
note 211 which is three scale steps down from D.

FIG. 3 illustrates one of the key dynamic
characteristics of the tone filter 107 -- that of
changing the filter schema within or between musical
sequences. FIG. 3 illustrates some of the options for
changing these filter schema termed "filter tables" in
the figure. The musical sequence represented by the
musical staff or "sample song" - 300 is displayed at
the top of the figure and four options for the
frequency of change of the filter tables 304 are
positioned below the musical staff purposely aligned to
show various possible frequencies for the change of

-13-

filter tables.   A change in the filter table is
represented by a vertical arrow 305 pointing upward, at
the relevant point in the musical sequence, as
represented by the musical staff.

The filter data associated with the musical
sequence can be set or changed once 302, at the
beginning of the musical sequence song and remain the
same throughout the song, or it may change every time
there is a change in a chord 303, or it may change
every measure 301 or fraction of a measure 306, or it
may change every note or fraction of a note 307. These
frequencies of filter table changes 302, 303, 306, 307
are some of the many options which can be employed to
change the filter schema or tables. These examples
represent differing degrees of sophistication of the
filter schema, and thus differing costs, as well as
memory requirements for the filter data 104 associated
with the musical background data. The more frequent
the change of filter tables, the more development time
and thus associated cost required to "score" or
annotated each musical sequence, and the more memory
required to store the filter data.

FIG. 4 is an illustration of an example of one of
the preferred embodiments of the invention. This
embodiment includes a console 400 with built-in speaker
403, a microphone or pickup 405, one or more musical
sequence or song ROM cartridge 401 with associated
filter data, and optional connectors for outside
amplification 408 or headphones 409. The cartridge for
the desired musical sequence is inserted into the
console. On the console, the user is offered the
control 402 over which specific musical sequence to
play as background if the cartridge contains more than
one such musical sequence. This configuration shows

-14-

four choices 402 but the embodiment could include any
number of choices of songs, depending on what is
determined to be economic to offer in the system's
largest available or planned cartridge. Also on the
console, the user is offered the control 404 over which
lead instruments are used to sound the output lead
tones 116. In addition, the console has master volume
control 407 and a "voice guide" selection 406, the
latter which enables "on" or disables "off" the tone
filter 107. The purpose of this control would be to
let singers choose to implement no correction to at
least the pitch in the source tone. Optional, but not
shown in this configuration, is a set of user controls
to activate and manipulate a harmony feature as
described in this application.

Although the present invention has been shown and
described with respect to preferred embodiments,
various changes and modifications which are obvious to
a person skilled in the art ow which the invention
pertains are deemed to lie within the spirit and scope
of the invention.

· -15-

What I claim as my invention is:

1. An entertainment device for enabling a user to easily play along with background music comprising:

pitch extracting means for extracting at least the fundamental pitch of an audio input signal,

first memory means for storing and transmitting background music information used to accompany the user,

second memory means for storing data associated with the background music defining at least a set of allowable output tone pitches,

filtering means supplied from the second memory means with the data associated with the background · music defining, at ·the minimum, a set of allowable output tone pitches to translate or map the fundamental pitch of the audio input signal to one of an allowable set of output lead tone pitches.

2. An entertainment device as set forth in claim 1, wherein the second memory means stores data defining at least a set of allowable output tone pitches and the filtering means translates at least the fundamental pitch of the input audio signal to one or more of an allowable set of output harmony tone pitches, which follow or harmonize with the output lead tone pitch.

3. An entertainment device as set forth in claims 1 or 2, further comprising a musical sound generator for reproducing the determined output tone pitches.

4. An entertainment device as set forth in claims 1

-16-

or 2, wherein the determined output tones are trans-
mitted through any external communicating means.

5.   An entertainment device as set forth in claim 4,
wherein the external communicating means is compatible
with the RS-232 standard.

6.   An entertainment device as set forth in claim 4,
wherein the external communicating means is a MIDI
(Musical Instrument Digital Interface).

7.   An entertainment device as set forth in claims 1,
2, 3, or 4, further comprising a musical sound
generator for reproducing the background musical
information. generator.

8.   An entertainment device as set forth in claims 1,
2, 3, or 4, further comprising an independent music
playing device for reproducing the background musical
information,

9.   An entertainment device as set forth in claim 8,
wherein the independent music playing device reproduces
audio signals from prerecorded media.

10.   An entertainment device as set forth in claim 8,
wherein the independent music playing device comprises
a microprocessor together with a prerecorded memory
device.

11.   An entertainment device as set forth in claim 1
wherein the means for storing and transmitting data
associated with the background music includes
information on the input tone interval, including the

starting time, stopping time, or duration of the tone, and the filtering means includes means for mapping the input tone interval to an allowable output tone interval.

12. An entertainment device as set forth in claim 1, wherein the filtering means generates a plurality of output tones from each input tone using the data associated with the background music and supplied by the first memory means to define an allowable relationship between each of the plurality of output tones.

13. An entertainment device as set forth in claims 1 or 2, further comprising user controls for allowing the user to choose between alternative musical sequences.

14. An entertainment device as set forth in claim 1, further comprising user controls for allowing the user to choose between alternative timbres personalities for the output tones.

15. An entertainment device as set forth in claim 1, wherein the embodiment includes a visual display of the lead tone note.

AMENDED CLAIMS
[received by the International Bureau on 23 May 1988 (23.05.88)
original claims 1 - 4 , 7 , 8 and 11 amended ; other claims unchanged (3 pages)]

What I claim as my invention is:

1.   An entertainment device for enabling a user
to easily play along with background music comprising:

first memory means for storing and transmitting
background music information, said information
consisting of a series of information units, each of
said information units representing at least pitch and
time values,

second memory means, connected to said first
memory means, for defining at least a set of allowable
pitch values for each of said information units in said
first memory means,

input means for accepting an audio signal,

pitch extracting means, connected to said input
means, for extracting at least the fundamental pitch of
the audio input signal,

filtering means, connected to said pitch
extracting means and said second memory means, for
converting said pitch extracted from said audio input
signal to one of said allowable pitch values, and

means for outputting a signal representing said
converted pitch value.

2.   An entertainment device as set forth in claim
1, wherein said allowable pitches stored in said
second memory means represent pitches which harmonize
with the pitch values in corresponding information
units in said first memory means.

3.   An entertainment device as set forth in
claims 1 or 2 further comprising a musical sound

generator, said generator having as its input said
signal representing the converted pitch value.

4.   An entertainment device as set forth in
claims 1 or 2, wherein said signal representing the
converted pitch value is transmitted through any
external communicating means.

5.   An entertainment device as set forth in claim
4, wherein the external communicating means is
compatible with the RS-232 standard.

6.   An entertainment device as set forth in
claim 4, wherein the external communicating means is a
MIDI (Musical Instrument Digital Interface).

7.   An entertainment device as set forth in
claims 1, 2, 3, or 4, further comprising a musical
sound generator for reproducing the background musical
information.

8.   An entertainment device as set forth in
claims 1, 2, 3, or 4, further comprising an independent
music playing device for reproducing the background
musical information.

9.   An entertainment device as set forth in
claim 8, wherein the independent music playing device
reproduces audio signals from prerecorded media.

10.   An entertainment device as set forth in
claim 8, wherein the independent music playing device

comprises a microprocessor together with a prerecorded memory device.

11.   An entertainment device as set forth in claim 1 wherein the first memory means stores background music information on the tone interval, including the starting time, stopping time, or duration of the tone, and the filtering means includes means for mapping the input tone interval to an allowable output tone interval.
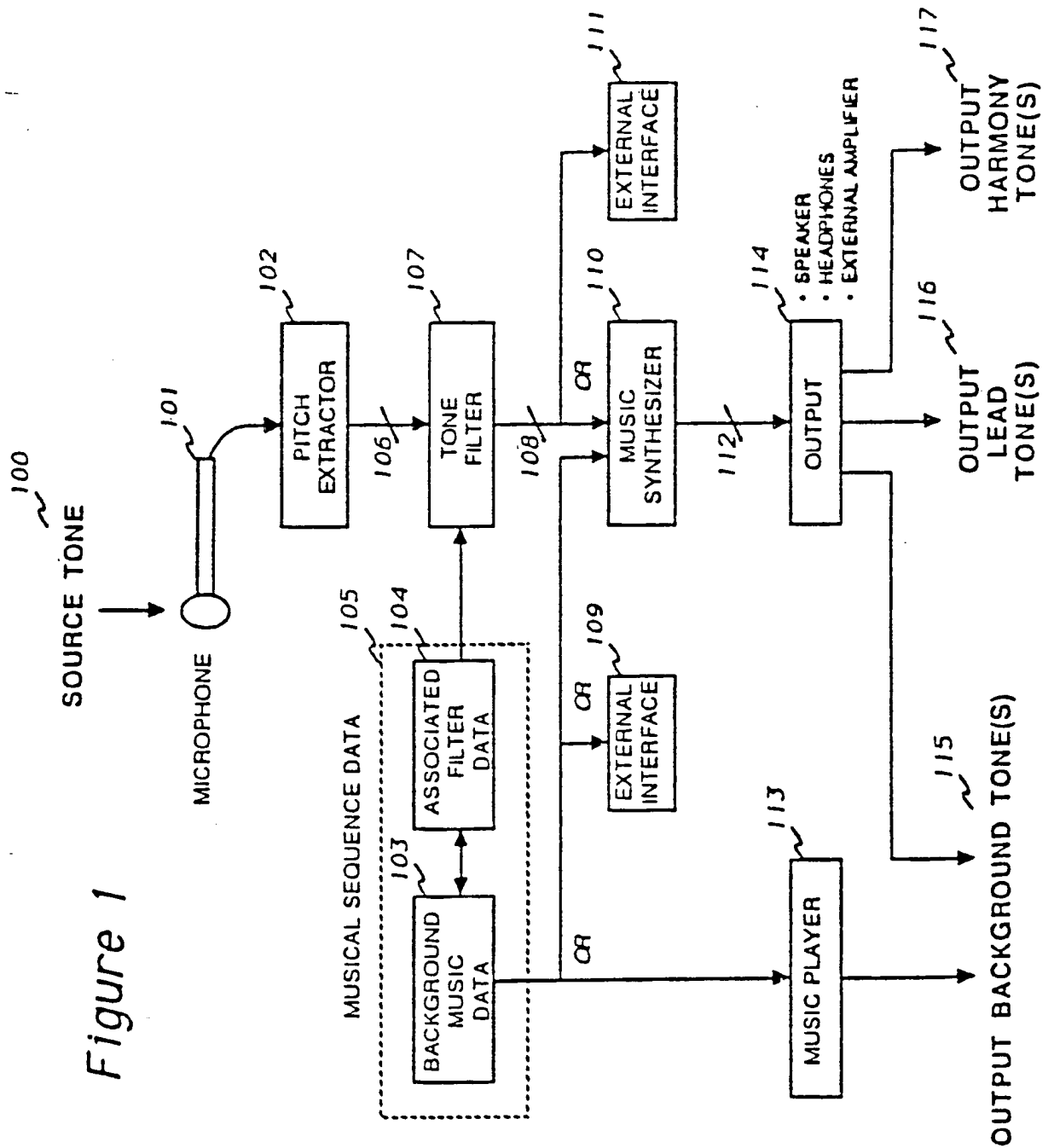
12.   An entertainment device as set forth in claim 1 wherein the filtering means generates a plurality of output tones from each input tone using the data associated with the background music and supplied by the first memory means to define an allowable relationship between each of the plurality of output tones.
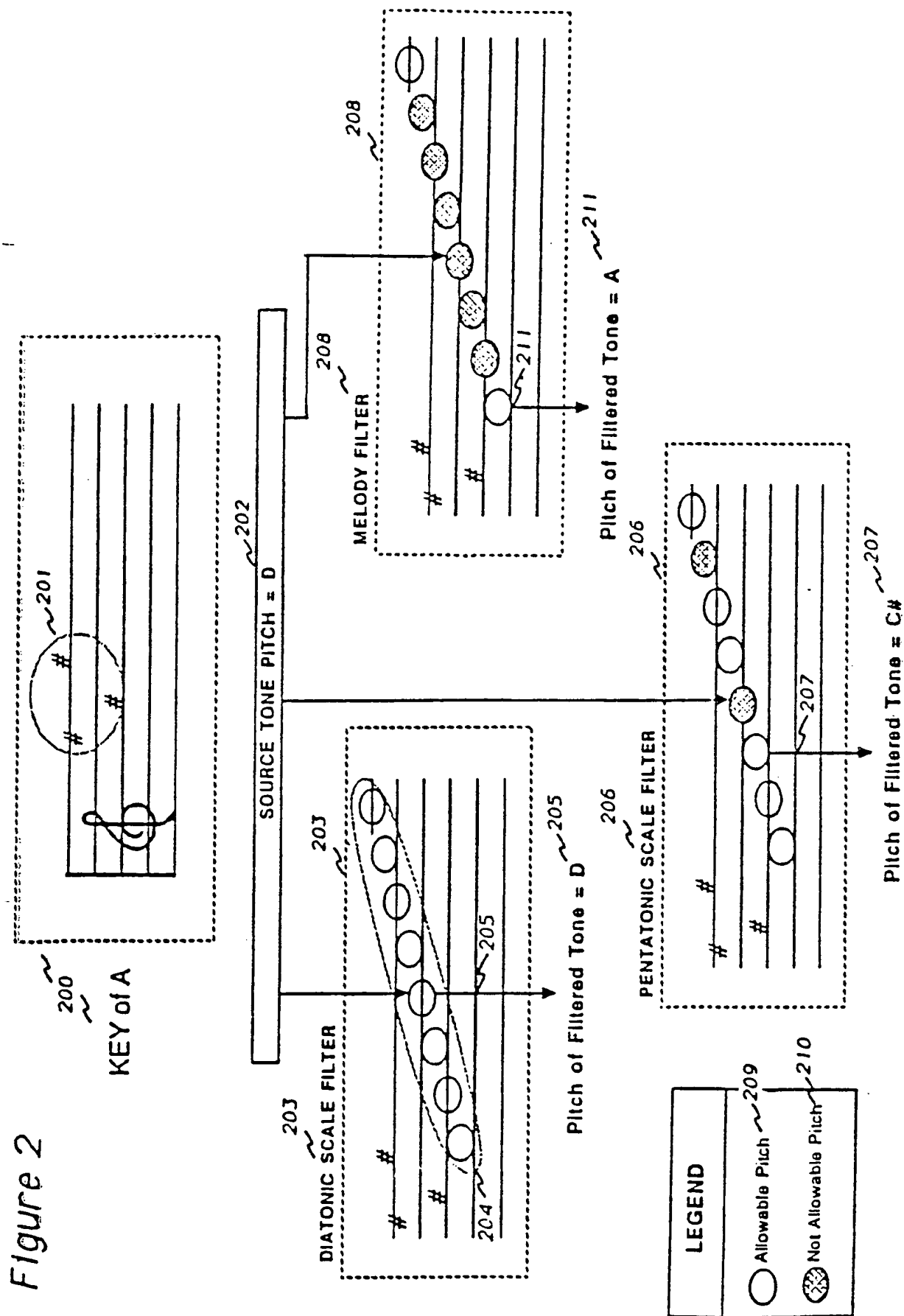
13.   An entertainment device as set forth in claims 1 or 2, further comprising user controls for allowing the user to choose between alternative musical sequences.

14.   An entertainment device as set forth in claim 1, further comprising user controls for allowing the user to choose between alternative timbres personalities for the output tones.

15.   An entertainment device as set forth in claim 1, wherein the embodiment includes a visual display of the lead tone note.
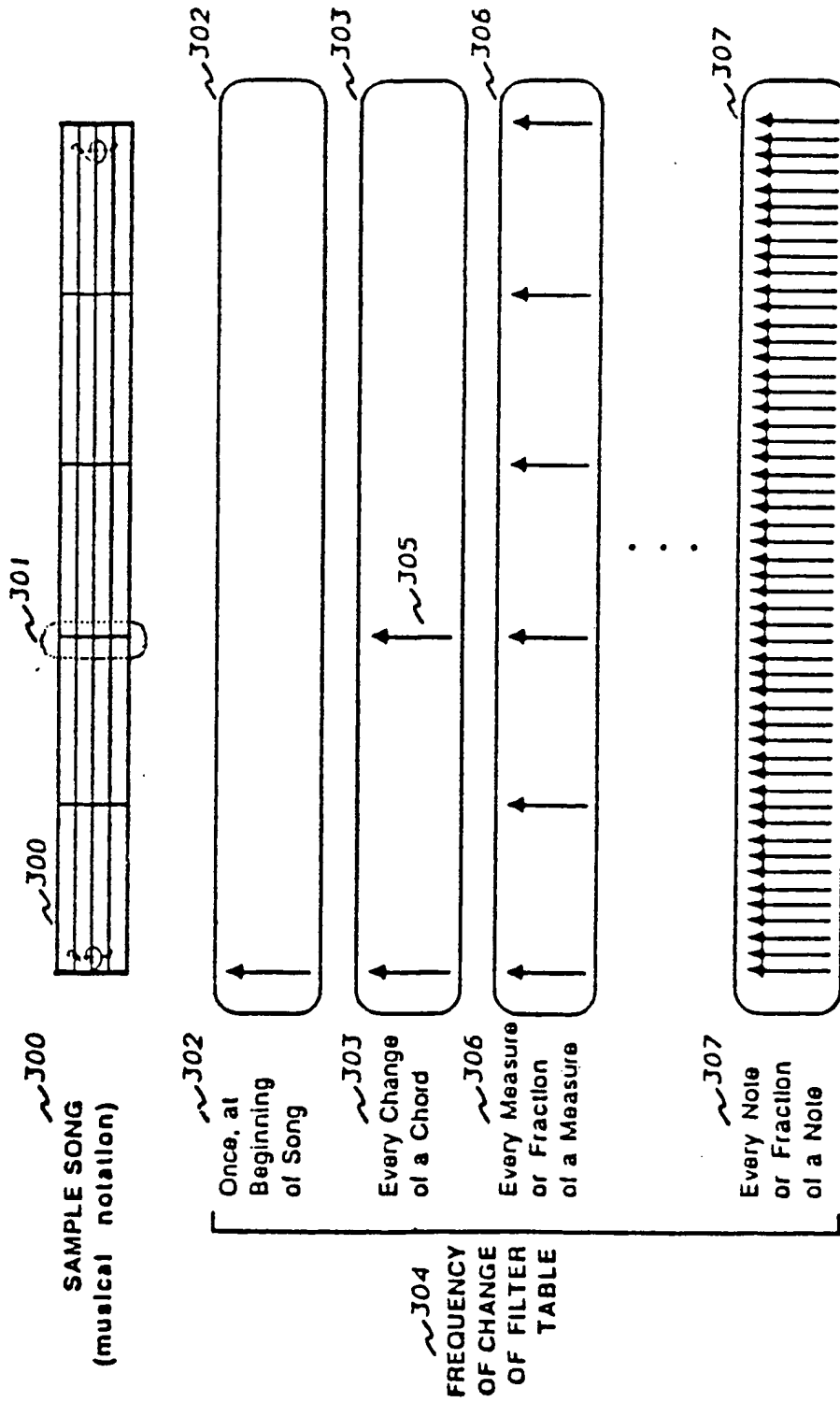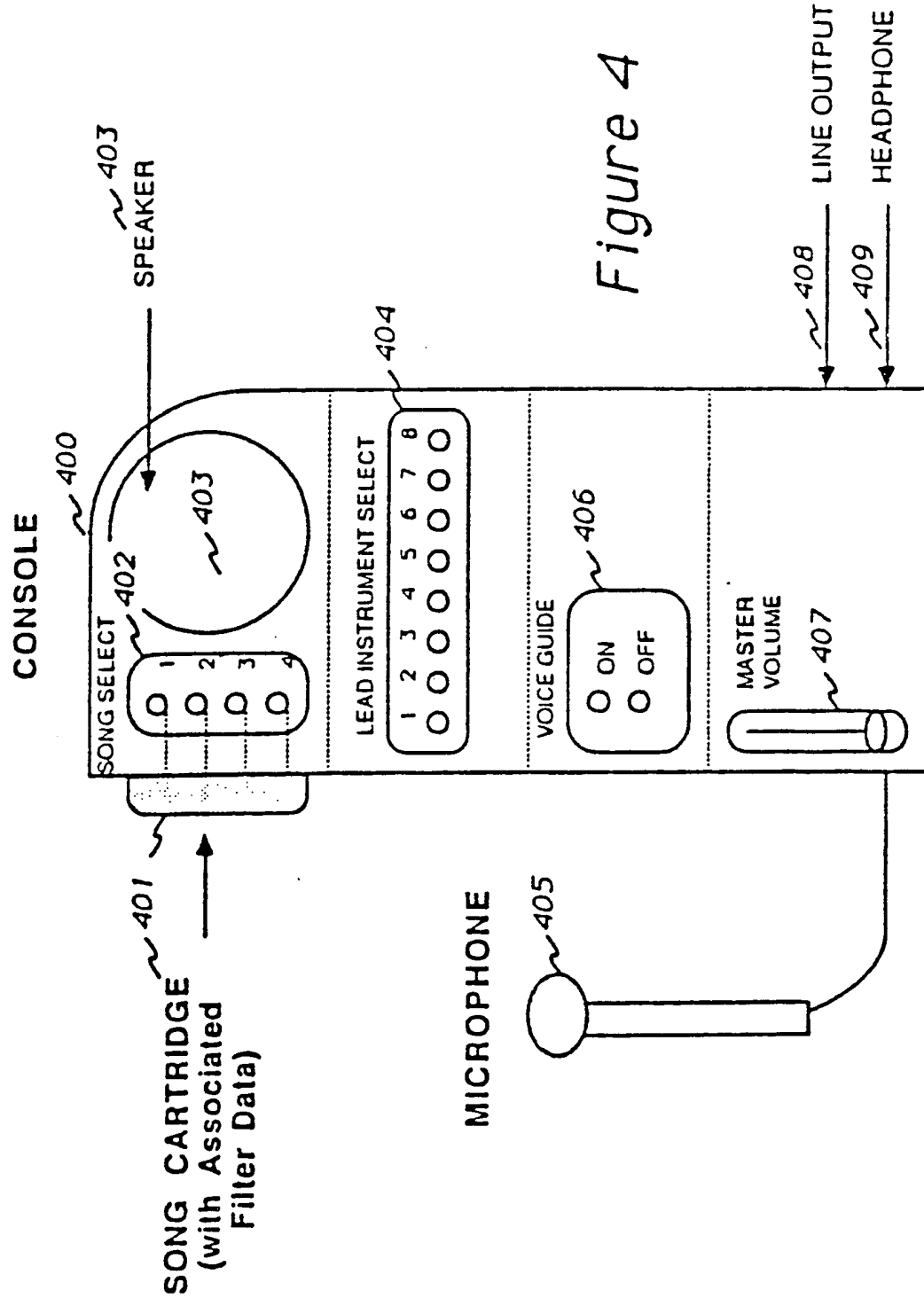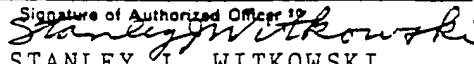
1 / 4

Figure 1

SOURCE TONE

Figure 2

Figure 3

4 / 4

Figure 4

INTERNATIONAL SEARCH REPORT

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) ³

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC (4): G 10G 1/00, G 10H 7/00
U.S. CL: 84/1.01, 1.28 453, 477.R, Digest 9, 18,29;381/49-51; 324/

II. FIELDS SEARCHED 78.R, 78.D, 79.R, 79D.

Minimum Documentation Searched ⁴

Classification System	Classification Symbols
U.S.	84/1.01, 1.28,453

Documentation Searched other than Minimum Documentation
to the Extent that such Documents are Included in the Fields Searched ⁶

III. DOCUMENTS CONSIDERED TO BE RELEVANT ¹⁴

Category *	Citation of Document, ¹⁶ with indication, where appropriate, of the relevant passages ¹⁷	Relevant to Claim No. ¹⁸
X	US, A, 4,441,399 (WIGGINS et al.) 10 April 1984, see the entire document.	1-15
X	US, A, 4,463,650 (RUPERT) 07 August 1984, see the entire document.	1-15
X	US, A, 3,999,456 (TSUNOO et al.) 28 December 1976, see the entire document.	1-15
X	EP, A, 142,935 (SEIKO INSTRUMENTS & ELECTRONICS LTD.) 29 MAY 1985, see the entire document.	1-15
A	US, A 3,539,701 (MILDE) 10 November 1970 see the entire document	1-15
A	US, A, 3,634,596 (RUPERT) 11 January 1972 see the entire document	1-15

* Special categories of cited documents: ¹⁵

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search ⁸	Date of Mailing of this International Search Report ⁹
03 MARCH 1988	25 MAR 1988
International Searching Authority ¹	Signature of Authorized Officer ¹⁰
ISA/US	STANLEY J. WITKOWSKI

Form PCT/ISA/210 (second sheet) (May 1986)

FURTHER INFORMATION CONTINUED FROM THE SECOND SHEET	
A US, A, 4,313,361 (DEUTSCH) 02 February 1982 see the entire document	1-15
A US, A, 4,377,961 (BODE) 29 March 1983 see the entire document	1-15
A US, A, 4,633,748 06 January 1987 see the entire document	1-15

V.☐ OBSERVATIONS WHERE CERTAIN CLAIMS WERE FOUND UNSEARCHABLE [10]

This international search report has not been established in respect of certain claims under Article 17(2) (a) for the following reasons:

1.☐ Claim numbers_____, because they relate to subject matter [12] not required to be searched by this Authority, namely:

2.☐ Claim numbers _____ , because they relate to parts of the international application that do not comply with the prescribed require-ments to such an extent that no meaningful international search can be carried out [13], specifically:

VI.☐ OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING [11]

This International Searching Authority found multiple inventions in this international application as follows:

1.☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims of the international application.

2.☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims of the international application for which fees were paid, specifically claims:

3.☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claim numbers:

4.☐ As all searchable claims could be searched without effort justifying an additional fee, the International Searching Authority did not invite payment of any additional fee.

Remark on Protest

☐ The additional search fees were accompanied by applicant's protest.

☐ No protest accompanied the payment of additional search fees.

Form PCT/ISA/210 (supplemental sheet (2) (May 1986)